

Jiro TANAKA\* & Mitsuo CHIHARA\*: **Taxonomic study of  
the Japanese crustose brown algae (1)  
General account and the order Ralfsiales**

田中次郎\*・千原光雄\*: 日本産殻状褐藻の分類学的研究 (1)

イソガラ目

The crustose brown algae have been systematically studied in detail in Europe and North America by several workers, notably Kuckuck (1894), Setchell and Gardner (1925), Waern (1949) and Hollenberg (1969). Hollenberg reported seven genera and eleven species of the crustose brown algae as the members of the Ralfsiales from the Pacific coast of North America, mostly from southern California.

There are few reports on the members of this algal group from Japan and the adjacent waters. As the first species found in Japan, Yendo (1909) recorded *Ralfsia fungiformis* (called as *R. deusta* (Ag.) J. Ag. by him) from Shiribeshi, Hokkaido. Later, several workers reported the occurrence of this species mostly from northern parts of Japan (*e.g.* from southern Saghalien by Tokida, 1954). A second species of *Ralfsia*, *R. verrucosa* which was first recorded by Yendo (1918) from Hakodate, Hokkaido, and it has been reported from many places along Japanese coasts. These are the only two species in the Ralfsiales reported from Japan to this time.

During our studies on the crustose brown algae from the Pacific coast of Japan, we have obtained additional information concerning their morphology and taxonomy. In a series of papers, we will deal with the taxonomy of the members of *Ralfsia*, *Endoplura* and *Diplura* of the Ralfsiaceae and *Pseudolithoderma* of the Lithodermataceae, all of which, except *Ralfsia*, have been found for the first time in Japan.

**Historical account of the order Ralfsiales**

To this time at least 17 genera of crustose brown algae have been des-

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cribed, and these taxa are often classified into three families, the Ralfsiaceae Hauck (1883), the Lithodermataceae Hauck (1883) and the Nemodermataceae Feldmann (1937). The Ralfsiaceae is generally considered as having a single chloroplast per cell. The Nemodermataceae, which is a monotypic family, is characterized by having intercalary unilocular sporangia. The genera *Petroderma* Kuckuck, *Sorapion* Kuckuck and *Symphyocarpus* Rosenvinge, which are generally considered to belong to the Lithodermataceae on the basis of their vegetative structure and reproductive organs, are unusual for that family in having a single chloroplast per cell. This fact may justify the conclusion that these families should not be distinguished from one another by the number of chloroplasts per cell. Recognizing this difficulty, Hollenberg (1969) included the Lithodermataceae in the Ralfsiaceae.

Nakamura (1972) established a new order Ralfsiales based on *Ralfsia* as the type genus, including certain crustose forms and, as an exception, including *Analipus* which have an erect thread. According to him, the Ralfsiales is characterized by having 1) an isomorphic life history, 2) development of a disc at an early stage of thallus formation and 3) having a single plate-like chloroplast lacking a pyrenoid in each cell. The Ralfsiales differs from the Chordariales, which has a heteromorphic life history, and differs from the Ectocarpales, which is filamentous and may form loosely branched prostrate system on germination.

The life history of the Ralfsiales was also studied by Loiseaux (1968) who confirmed that *Ralfsia verrucosa*, *R. clavata* and *Pseudolithoderma roscoffensis* have isomorphic life history. A similar result was obtained on studies of another clone of *R. verrucosa* from eastern Canada by Edelstein *et al* (1971).

Nakamura (1965), Tatewaki (1966), Wynne (1969) and Nakamura and Tatewaki (1975) have shown that a *Ralfsia*-like stage occurs in the life history of the members of the Scytosiphonales erected by Feldmann (1949). Edelstein *et al.* (1970) have also shown that spores of two species of *Ralfsia*, *R. clavata* and *R. borneti*, give rise to a blade-like thallus belonging to the Scytosiphonales. Moreover, Nakahara and Nakamura (1977) have reported that *Hapterophycus canaliculatus*, which originally was placed in the Ralfsiaceae, exhibits a creeping-type of development of the thallus, and its life history is of the *Scytosiphon*-type. According to Nakamura's proposal (1972), these algae should be excluded from the Ralfsiaceae because of their heteromorphic life

history and their being only a phase in the life history of certain species of the Scytosiphonales.

Nakamura (1972) included the three families mentioned above in his discussion of the Ralfsiales, with the following characterization which was mainly based on the position of the reproductive organs. In the family Ralfsiaceae, the unilocular sporangia are lateral and the plurilocular reproductive organs are intercalary, whereas in the family Lithodermataceae, both kinds of reproductive organs are terminal on the vegetative filaments. In the family Nemo-dermataceae, the unilocular sporangia are intercalary and the plurilocular reproductive organs are lateral. His system seems to be very clear-cut and more natural and has been completely accepted by Bold and Wynne (1978). In the present study, we will follow Nakamura's system, but will not consider the number of chloroplasts in a cell as one of the order's characters. As described later in detail, some members of the Ralfsiales, including *Endoplura* and *Diplura* of the Ralfsiaceae, and *Pseudolithoderma* of the Lithodermataceae, have several chloroplasts and their shapes are discoidal or irregular in contrast to *Ralfsia* in which chloroplasts are plate-like, according to Nakamura (1972). In addition to this evidence, it should also be cited that Loiseaux (Wynne & Loiseaux, 1976) reported a chloroplast with a pyrenoid for a *Ralfsia clavata* which was not of subgenus *Stragularia*, and, moreover, Fletcher (1978) confirmed the presence of pyrenoids in some members of *Ralfsia*, including *R. verrucosa*.

With regards the systematic position of *Analipus japonicus* (= *Heterochordaria abietina*), Nakamura (1972) was of the opinion that it should be included in the Ralfsiales on account of having the disc type of germination. Wynne (1972) has been inclined to agree with Nakamura in treatment *Ralfsia* and *Analipus* in the same taxonomic entity. We also agree with both as to the systematic position of *Analipus*, but it is excluded from a series of our papers since it has both a crustose basal system and an erect system.

#### Morphological characters for the classification within the order Ralfsiales

The vegetative thallus of the Ralfsiales has a simple construction: it is composed of basal layer and erect filaments (vegetative filaments). The following vegetative characters have been used as diagnostic criteria within the Ralfsiales, for the identification of taxa, mainly at the rank of species: 1).

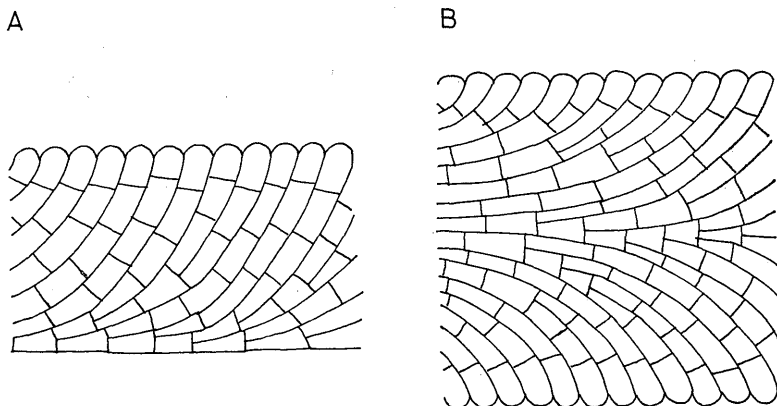


Fig. 1. Diagrammatic figures showing two types of the thallus structure found in *Ralfsia* species.  
A. Vegetative filaments curving only upwards (unilateral structure). B. Vegetative filaments curving both upwards and downwards (symmetric bilateral structure).

how tightly erect filaments are joined with one another, 2) whether erect filaments are curved or straight and 3) whether a thallus has a symmetric bilateral or a unilateral form (Fig. 1-A, B).

As mentioned above, the number of chloroplasts cannot be used as criterion for distinguishing the Ralfsiaceae from the Lithodermataceae. However, it can be used as a diagnostic character for distinguishing certain genera within the Ralfsiales (e.g. *Ralfsia* and *Endoplura*). Many characters associated with reproductive organs, unilocular and plurilocular, can be useful for the classification of this algal group. In *Ralfsia*, unilocular sporangia are formed in the following way. An apical cell of an erect vegetative filament divides terminally, ultimately giving rise to multicellular paraphyses (Fig. 2; 1-2). When the formation of paraphysis has been completed, its supporting cell, that is, the cell in the position of the original apical cell of the erect filament, divides obliquely forming a cell that becomes a unilocular sporangium (Fig. 2; 3). The initial cell is conical at first, but later becomes clavate or oblongate in shape, standing more or less upright on the apical cell of the erect filaments (Fig. 2; 4-5). A similar process in the formation of unilocular sporangia was described by Edelstein *et al.* (1969) for *R. fungiformis*. The unilocular sporangium may or may not have stalk cells, depending on the species. The presence or absence and the number of the stalk cells are, therefore, useful

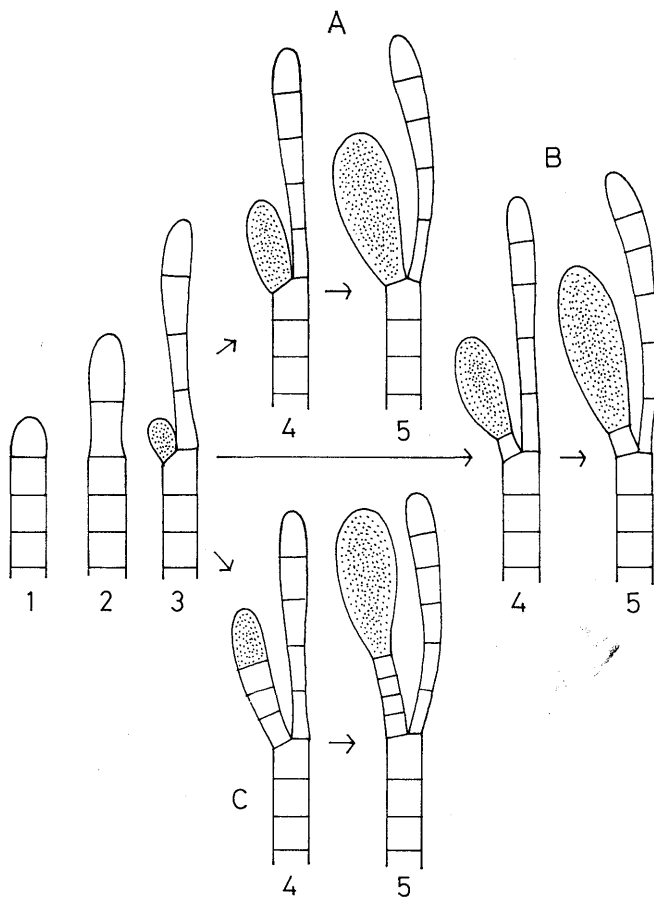


Fig. 2. Diagrammatic figures showing successive stages in the formation of unilocular sporangia found in *Ralsfia* species from Japan. A. Sporangia without a pedicel. B. Sporangia with a unicellular pedicel. C. Sporangia with a multicellular pedicel. (1, Vegetative stage; 2, Development of paraphysis; 3, An initiation of unilocular sporangium; 4, Formation of stalk cells at the base of sporangium; 5, Mature stage; Sporangia, including the initial cell, are stippled).

criteria at the rank of species or subgenera. On the basis of these characters, *Ralsfia* can be classified into three groups: 1) a group without stalk cells (Fig. 2; A), to which *Ralsfia fungiformis*, *R. verrucosa*, *R. integra*, *R. tenuis* and *R. borneti* belong, 2) a group with a single celled stalk (Fig. 2; B),

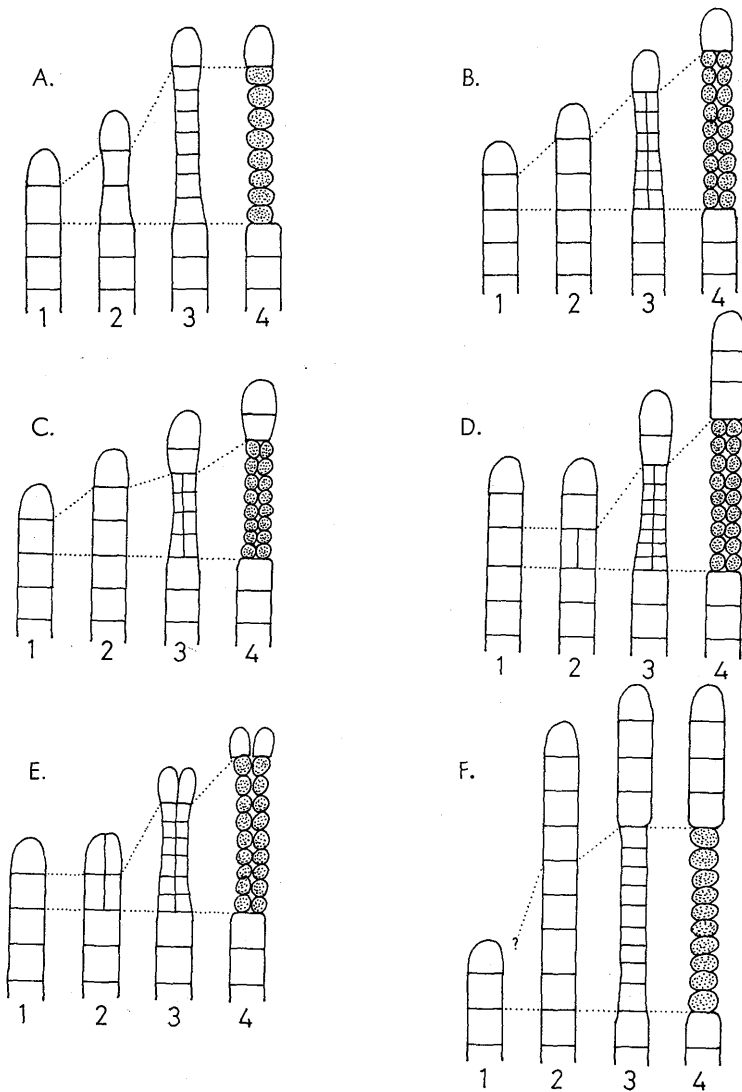


Fig. 3. Diagrammatic figures showing successive stages in the formation of plurilocular reproductive organs found in the Ralfsiaceae from Japan. A. *Ralfsia verrucosa*, B. *R. expansa*, C. *R. pedicellata*, D. *R. endoplurioides* and *Endoplura*, E. *Diplura*, F. *R. fungiformis*. (1, Vegetative stage; 2, Divisions of potential fertile cells; 3, Further divisions of fertile cells and development of terminal sterile cells; 4, Mature stage; Reproductive cells are stippled).

to which *R. pedicellata* belongs and 3) a group with a stalk consisting of more than one cell (Fig. 2; C), to which *R. expansa* belongs.

Characters such as the length of paraphyses and the number of cells in the paraphyses and the size and the shape of the unilocular sporangia have been used as diagnostic criteria important primarily for determining species of *Ralfsia* and the related taxa by many phycologists, including Hollenberg (1969). These features are used as additional characters in the present study since they are apt to vary depending on the maturity of the organs, and also on the ecological conditions.

According to the classification currently accepted by majority of phycologists, one of the main characters at the generic rank within the Ralfsiaceae concerns the plurilocular reproductive organs. In the present study it is confirmed that all of the taxa examined in the Ralfsiaceae share the following features of the plurilocular organs: 1) the origin is initiated from a certain cell which submerges but not far from the surface of the erect filament (Fig. 3; 1-2), 2) the initial cell develops and gives rise to one to four rows of filaments, consisting of reproductive cells arranged in series, which we term "plurilocular reproductive filaments" (Fig. 3; 3-4), and 3) cells located on the top of the organ do not become fertile, but remain sterile, which we term "sterile filament or sterile cell" (Fig. 3; 4). Using a combination of these features, the Japanese representatives of the Ralfsiaceae can be separated from one another fairly well as follows: *Ralfsia verrucosa* has a single plurilocular reproductive filament with one sterile terminal cell per filament (Fig. 3; A), *R. expansa* in which there are two plurilocular reproductive filaments with two uniseriately arranged terminal cells are present (Fig. 3; C), *Endoplura aurea* and *Ralfsia endopluroides*, in which two or four reproductive filaments occur with three uniseriately arranged terminal cells (Fig. 3; D), *Diplura simplex*, in which two plurilocular reproductive filaments are present with one terminal cell on each of the filaments (Fig. 3; E) and *R. fungiformis*, in which one plurilocular reproductive filament occurs with three to six terminal sterile cells (Fig. 3; F). The features mentioned above with the species of *Endoplura* and *Diplura* have been used as criteria for characterizing those genera, respectively, by Hollenberg (1969). In view of this evidence, the features of plurilocular reproductive organs are used in the present study as characters important primarily at the rank of species or genera of the Ralfsiaceae.

### Key to the families and genera of the Ralfsiales from Japan

- 1 Both plurilocular and unilocular reproductive organs borne terminally on the vegetative filaments; paraphyses not formed .....  
..... *Pseudolithoderma* (*P. subextensum*)  
(Lithodermataceae)
- 1 Plurilocular reproductive organs intercalary in vegetative filaments, with one to several terminal sterile cells; unilocular sporangia borne laterally on the vegetative filaments; paraphyses present ..... 2  
(Ralfsiaceae)
- 2 Chloroplasts disc shaped or irregular in shape and several per cell ..... 3
- 2 Chloroplasts plate shaped and one per cell ..... *Ralfsia*
- 3 Plurilocular reproductive organ bearing three sterile cells in a terminal uniseriate series ..... *Endoplura*
- 3 Plurilocular reproductive organs bearing a single terminal sterile cell in each reproductive filament ..... *Diplura*

**Acknowledgement** We wish to express our gratitude to Dr. Richard E. Norris of the University of Washington for his kind reading of the manuscript. Thanks are also due to Mr. Makoto Yoshizaki of Toho University and Drs. Yoshiaki Hara and Takaaki Kobara of our laboratory for their generous aids in the course of the present study.

This paper constitutes Contributions from the Shimoda Marine Research Center, The University of Tsukuba, No. 365.

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本報告は邦産殻状褐藻の分類学的研究の第一報で、多くの殻状褐藻が所属するイソガ

ワラ目について体構造や生殖器官等の観察結果を述べ、従来の研究結果も総合して、それらの分類形質としての評価を考察した。また最近、培養の研究から殻状褐藻には異なる分類群の生活環の世代に過ぎないものがある事実が知られてきたので、それらの経過についてもふれた。最後に邦産イソガラワラ目の科と属の検索表を与えた。

○キク科の帰化植物ハチミツソウ追記(浅井康宏) Yasuhiro ASAI: Additional notes on *Verbesina alternifolia* (L.) Britton in Japan

最近、各地の向陽の路傍、荒地などから散在的に、茎が米名 Wingstem が示すように有翼で、Fig. 1 および 2 のような特徴ある舌状花と瘦果とをもつキク科植物の帰化が認められている。この植物は京都大学理学部の村田源氏によれば、*Verbesina alternifolia* (L.) Britton であり、その扁平有翼な瘦果に因んでハネミギクなる名を提示された (Acta Phytotax. Geobot. 28: 44, 1977)。



Fig. 1. *Verbesina alternifolia* (L.) Britton with flowers and immature fruits at Setagaya, Tokyo (Photo by Y. Asai, Sept. 16, 1976).

ところで筆者も1970年頃から、本種と思われる植物の標本や生品に接する機会を得、爾来、その一部を自庭に栽植し、観察、検討を加えてきた。その結果、やはり村田氏と同様にアメリカ合衆国原産の上記学名に該当するものと判定するに至った。

しかしながら本属の外来品には、かつて久内清孝先生が名古屋の井上丹治氏により蜜源植物として輸入、栽培されたものに基づきハチミツソウ *Verbesina occidentalis* (L.) Walter なる名で報告された植物 (Journ. Jap. Bot. 38: 375, 1963) があり、これとの関連が気にかかっていた。そこで改めて、東京大学理学部所蔵の標本を検討してみたところ、久内先生の扱われたものは *V. occidentalis* ではなく、*V. alternifolia* そのものであるとの結論に到達した。因みに東大には本種の標本として、長